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भाग 1 मृदु चुम्बकीय सामग्री

Indian Standard

GLOSSARY OF TERMS RELATING TO SPECIAL ALLOYS

PART 1 SOFT MAGNETIC MATERIALS

UDC 669·018·5 : 001·4

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

August 1993 **Price Group 3**

Special Metals and Alloys Sectional Committee, MTD 27

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Special Metals and Alloys Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard has been prepared for the guidance of manufacturers and consumers to assist them in the correct interpretation of common terms used in special alloys. It is hoped that this glossary of terms will help in establishing a generally recognized usage and eliminate ambiguity and confusion that might arise from individual interpretation of terms. This standard is intended mainly to cover technical definitions of terms relating to soft magnetic materials, and it does not necessarily include all the legal meaning of the terms.

Conversion factors from Gaussian to SI units are given in Annex A for information and guidance only.

In the preparation of this standard, assistance has been derived from ASTM A 340-1986 'Terminology of symbols and definitions relating to magnetic testing' issued by the American Society for Testing and Materials (ASTM) and BS 4727 : Part 1 Group 07 : 1973 'Magnetism terminology' issued by the British Standards Institution (BSI).

Indian Standard

GLOSSARY OF TERMS RELATING TO SPECIAL ALLOYS

PART 1 SOFT MAGNETIC MATERIALS

1 SCOPE

This standard (Part 1) is intended to define and explain the terms commonly used in different production units of soft magnetic materials.

2 DEFINITIONS

A

2.1 Active (Real) Power, P — The product of the rms current I in an electrical circuit, the rms voltage E across the circuit and the cosine of the angular phase difference θ between the current and the voltage $P = EI \cos \theta$. The SI Unit is watt.

2.2 Ageing Coefficient — The percentage change in a specific magnetic property resulting from a specific ageing treatment.

2.3 Ageing Magnetic — The change in the magnetic properties of a material resulting from metallurgical change. This term applies whether the change results from a continued normal or a specified accelerated ageing condition.

2.4 Ampere — Turn — The SI unit of magnetomotive force, equal to the magnetomotive force produced by a current of one ampere flowing through one turn of a conductor. One ampere — turn equals $4 \frac{\pi}{10}$ or 1·257 gilberts.

2.5 Ampere per Metre (Ampere — Turn per Metre) — The SI unit of magnetic field strength (magnetic intensity, magnetizing force). One ampere per metre equals $4\pi \times 10^{-3}$ or 0·012 57 oersted.

2.6 Anisotropic Material — A material in which the magnetic properties differ in various directions.

2.7 Area — The geometric cross-sectional area of magnetic path which is perpendicular to the direction of the induction. The SI Unit is square metre.

B

2.8 Bohr Magneton — A constant ($9{\cdot}274\,078 \times 10^{-21}$ erg/gauss or $9{\cdot}274\,078 \times 10^{-24}$ joule per tesla or ampere square metre) that is equal to the magnetic moment of an electron due to its spin.

C

2.9 Coercive Force, H_c — The (d.c.) magnetizing force at which the magnetic induction is zero when the material is in a symmetrically cyclically magnetized condition. The SI Unit is ampere per metre.

2.10 Coercive Force Intrinsic, H**ci** — The (d.c.) magnetizing force at which the intrinsic induction is zero when the material is in a symmetrically cyclically magnetized condition. The SI Unit is ampere per metre.

2.11 Coercivity, H_{cs} — The maximum value of coercive force.

2.12 Core Laminated — A magnetic core constructed by stacking thin pieces of suitable shape, which are stamped or sheared from sheet or strip material. Individual pieces usually have an insulating surface coating to minimize eddy current losses in the assembled core.

2.13 Core Loss, Specific P_c (B, f) — The active power (watts) expended per unit mass of magnetic material in which there is a cyclically varying induction of a specified maximum value, B, at a specified frequency f.

2.14 Core, Loss (Total), P_c — The active power (watts) expended in a magnetic circuit in which there is a cyclically alternating induction.

2.15 Curie Temperature, T_c — The temperature above which a ferromagnetic material becomes paramagnetic. The SI Unit is the kelvin.

2.16 Cyclically Magnetized Condition — A magnetic material is in a cyclically magnetized condition when, after having been subjected to a sufficient number of identical cycles of magnetizing force, it follows identical hysteresis or flux-current loops on successive cycles which are not symmetrical with respect to the origin of the axes.

D

2.17 Demagnetization Curve — That portion of a normal (d.c.) hystersis loop which lies in the second or fourth quadrant, that is, between the residual induction point, B_r, and the coercive force point, H_c. Points on this curve are designated by the coordinates, B_d and H_d.

2.18 Domains, Ferromagnetic — Magnetized regions, either macroscopic or microscopic in size, within ferromagnetic materials. Each domain, per se, is magnetized to intrinsic saturation at all times, and this saturation induction is unidirectional within the domain.

2.19 Domain Wall — A boundary region between two adjacent domains within which the orientation of the magnetic moment of one domain changes into a different orientation of the magnetic moment in the other domain.

E

2.20 Eddy Current Loss, Normal P_e — That portion of the core loss which is due to induced currents circulating in the magnetic material subject to a symmetrically cyclically magnetized excitation.

2.21 Electrical Steel — A term used commercially to designate a flat-rolled iron-silicon alloy used for its magnetic properties.

F

2.22 Ferrimagnetic Material — A material in which unequal magnetic moments are lined up antiparallel to each other. Permeabilities are of the same order of magnitude as those of ferromagnetic materials, but are lower than they would be if all atomic moments were parallel and in the same direction. Under ordinary conditions the magnetic characteristics of ferrimagnetic materials are quite similar to those of ferromagnetic materials.

2.23 Ferrite — A term referring to magnetic oxides in general, and especially to material having the formula $MOFe_2O_3$ where M is a divalent metal ion or a combination of such ions. Certain ferrites, magnetically 'soft' in character, are useful for core applications at radio and higher frequencies because of their advantageous magnetic properties and high volume resistivity. Other ferrites, magnetically 'hard' in character, have desirable permanent magnetic properties.

2.24 Ferromagnetic Material — A material that, in general, exhibits the phenomena of hysteresis and saturation, and whose permeability is dependent on the magnetizing force.

2.25 Flux Path Length — The distance along a flux loop.

2.26 Flux Path Length, Effective — In a magnetic core, the equivalent mean length of the flux path which is used in the calculation of certain magnetic parameters.

G

2.27 Gauss (Plural Gausses) — The unit of magnetic induction in the cgs electromagnetic system. The gauss of equal to 1 maxwell per square centimetre or 10^{-4} tesla.

2.28 Gilbert — The unit of magnetomotive force in the cgs electromagnetic system. The gilbert is a magnetomotive force of 10 ampere-turns.

H

2.29 Hysteresis Loop, Intrinsic – A hysteresis loop obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding d.c. values of intrinsic induction B, for ordinates and magnetizing force H for abscissae.

2.30 Hysteresis Loop, Normal — A closed curve obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding d.c. values of magnetic induction (B) for ordinates and magnetizing force (H) for abscissa when the material is passing through a complete cycle between equal definite limits of either magnetizing force $\pm H_m$, or magnetic induction $\pm B_m$. In general the normal hysteresis loop has mirror symmetry with respect to the origin of the B and H axes but this may not be true for special materials.

2.31 Hysteresis Loss, Normal, P_h (1) — The power expended in a ferromagnetic material, as a result of hysteresis, when the material is subjected to a symmetrically cyclically magnetized excitation.

2.32 Hysteresis Loss, Normal, P_h (2) — The energy loss per cycle in a magnetic material as a result of magnetic hysteresis when the induction is cyclic (not necessarily periodic).

2.33 Hysteresis Magnetic — The property of a ferromagnetic material exhibited by the lack of correspondence between the changes in induction resulting from increasing magnetizing force and from decreasing magnetizing force.

I

2.34 Induction, Intrinsic, Bi — The vector difference between the magnetic induction in a magnetic material and the magnetic induction that would exist in a vacuum under the influence of the same magnetizing force. See magnetic induction (flux density).

2.35 Induction, Maximum B_m (1) — The maximum value of magnetic induction, B, in a hysteresis loop. The tip of this loop has the magnetostatic coordinates H_m, B_m which exist simulataneously.

2.36 Induction, Maximum, B_m (2) — B_{max} the maximum value of induction in a flux-current loop.

2.37 Induction, Normal, B — The maximum induction, in a magnetic material that is in a symmetrically cyclically magnetized condition.

NOTE — Normal induction is a magnetostatic parameter usually measured by ballistic methods.

2.38 Induction, Remanent, B_d — The magnetic induction that remains in a magnetic circuit after the removal of an applied magnetomotive force.

2.39 Induction, Residual, B_r — The magnetic induction corresponding to zero magnetizing force in a magnetic material that is in a symmetrically magnetized condition.

2.40 Induction, Saturation, B_s — The maximum intrinsic induction possible in a material.

2.41 Induction Curve, Intrinsic (Ferric) — A curve of a previously demagnetized specimen depicting the relation between intrinsic induction and corresponding ascending values of magnetizing force. This curve starts at the origin of the B_i and H axes.

2.42 Induction Curve, Normal — A curve of a previously demagnetized specimen depicting the relation between normal induction and corresponding ascending values of magnetizing force. This curve starts at the origin of the B and H axes.

2.43 Isotropic Material — Material in which the magnetic properties are same for all directions.

M

2.44 Magnetic Circuit – A closed path formed by magnetic lines of force. The concept is very important in electrical engineering; it compares directly to an electrical circuit. Magnetomotive force compares to electromotive force; magnetic flux is the analogue of current; reluctance is like resistance.

2.45 Magnetic Constant (Permeability of Space), μ_0 — A constant equal to $4\pi \times 10^{-7}$ henry per metre. Its value is unity and has no dimension in the cgs-electro magnetic system.

NOTE — For practical purposes this constant, when multiplied by the field strength equals the flux-density in vacuum.

2.46 Magnetic Dipole Moment, j — The product of the magnetic constant and the magnetic (area) moment. The SI Unit is weber meter.

2.47 Magnetic Flux, ϕ — The product of the magnetic induction B, and the area of a surface (or cross-section) A, when the magnetic induction B is uniformly distributed and normal to the plane of the surface.

$$\phi = BA$$

where

ϕ = magnetic flux,
B = magnetic induction, and
A = area of the surface.

Magnetic flux is a scalar and has no direction. The SI Unit is weber.

2.48 Magnetic Flux Density, B — *See* magnetic induction (flux density).

2.49 Magnetic Induction (Flux Density) — That magnetic vector quantity which at any point in a magnetic field is measured either by the mechanical force experienced by an element of electric current at the point, or by the electromotive force induced in an elementary loop during any change in flux linkages with the loop at the point. The SI Unit is tesla.

NOTE — The magnetic induction, B, is uniformly distributed and normal to a surface or cross-section, then the magnetic induction is :

$$B = \phi / A$$

where

B = magnetic induction,
ϕ = magnetic flux, and
A = area of surface.

2.50 Magnetic Line of Force — An imaginary line in a magnetic field which at every point has the direction of magnetic induction at that point. One weber equals 10^8 lines.

2.51 Magnetic (Area) Moment, m — A measure of the magnetizing force, H produced at points in space by a plane current loop or a magnetized body. It relates to the turning effect (moment) on it when in a given field. It is defined as the torque observed in a unit field at 90° to the magnetic axis. For a coil with 'N' turns and area 'A', carrying a current 'I'.

$$m = NIA$$

In this case m is often called the electromagnetic moment of the coil. The SI Unit is ampere square meter.

2.52 Magnetic Polarization, J — A vector associated with the volume, v of a material and equal to the total magnetic dipole moment $\vec{j}$ of that volume, divided by the volume.

$$\vec{J} = \frac{\Sigma \vec{j}}{v}$$

It can be interpreted as the volume density of magnetic dipole moment, $\vec{j}$. The SI Unit is tesla (weber per square metre).

2.53 Magnetization, *M* — A vector associated with the volume, of a material, equal to the total magnetic moment of that volume divided by the volume.

$$\vec{M} = \frac{\Sigma \vec{m}}{v}$$

It can be interpreted as volume density of magnetic moment, $\vec{m}$. The SI Unit is ampere per metre. Sometimes magnetization, *M* can be expressed as μ_B/atom, μ_B/formula unit etc.

NOTE — The term magnetization may also be used in a qualitative sense to mean the process of magnetizing. Where confusion may arise it is possible to use the term 'magnetization strength' for the vector quantity.

2.54 Magnetization, Saturation, M_s — The maximum obtainable magnetization for a given material at a given temperature.

2.55 Magnetizing Force (Magnetic Field Strength), *H* — That magnetic vector quantity at a point in a magnetic field which measure the ability of electric currents on magnetized bodies to produce magnetic induction at the given point. The SI Unit is ampere per meter.

2.56 Magnetomotive Force, *F* **(Magnetic Portenital, m.m.f)** — The integral of magnetic field strength, H around a closed path that is $\int \vec{H}.\vec{dl}$. The SI Unit is ampere turn. Magnetomotive force is analogous to electromotive force in electric circuits

2.57 Maxwell — The unit of magnetic flux in the cgs electromagnetic system. One maxwell equals 10^{-8} weber.

N

2.58 Non-oriented Electrical Steel — A flat rolled electrical steel which has approximately the same magnetic properties in all directions.

O

2.59 Oersted — The unit of magnetizing force (magnetic field strength) in the cgs electromagnetic system. One oersted equals a magnetomotive force of 1 gilbert/cm of flux path. One oersted equals 1 000/4π or 79·58 ampere per metre.

P

2.60 Permeability, a.c. — A generic term used to express various dynamic relationship between magnetic induction, *B*, and magnetizing force, *H*, for magnetic material subjected to a cyclic excitation by alternating or pulsating current. The values of a.c. permeability obtained for a given material depend fundamentally upon the excursion limit of dynamic excitation and induction, the method and conditions of measurement, and also upon such factors as resistivity, thickness of laminations, frequency of excitation, etc.

2.61 Permeability, d. c. — Permeability is a general term used to express relationship between magnetic induction, *B*, and magnetizing force, H under various conditions of magnetic excitation. These relationships are either (1) absolute permeability, which in general is the quotient of a change in magnetic induction divided by the corresponding change in magnetizing force, or (2) relative permeability, which is the ratio of the absolute permeability to the magnetic constant.

2.62 Permeability, Initial, μ_i — The limiting value approached by the normal permeability as the applied magnetizing force *H*, is reduced to zero. The permeability is equal to the slope of the normal induction curve at the origin of linear *B* and *H* axes.

2.63 Permeability, Maximum, μ_m — The value of normal permeability for a given material where a straight line from the origin of linear *B* and *H* axes becomes tangent to the normal induction curve.

2.64 Permeability, Normal, μ — The ratio of the normal induction to the corresponding magnetizing force. It is equal to the slope of a straight line joining the limits of a normal hysteresis loop or the slope of a straight line joining any point (*H*m, *B*m) on the normal induction curve to the origin of the linear *B* and *H* axes.

R

2.65 Reluctance (Magnetic Resistance), *R* — The ratio of magnetomotive force to total magnetic flux in a magnetic circuit. It is the magnetic analogue of electric resistance. The SI Unit is henry per metre (ampere per weber metre).

The reciprocal of the reluctance is known as permanence.

2.66 Retentivity, B_{rs} — That property of a magnetic material which is measured by its maximum value of the residual induction (retentivity is usually associated with saturation induction). It is also known as remanence.

S

2.67 Symmetrically Cyclically Magnetized Condition — A magnetic material is in a symmetrically cyclically magnetized condition when, under the influence of a magnetizing force that varies cyclically between two equal positive and negative limits, its successive hysteresis loops or flux-current loops are both identical and symmetrical with respect to the origin of the axes.

T

2.68 Tesla — The SI Unit of magnetic induction. One tesla is equal to one weber per square metre or 10^4 gausses.

W

2.69 Watt — The SI Unit of active power. One watt is a power of one joule per second.

2.70 Weber — The SI Unit of magnetic flux. The weber is the magnetic flux whose decrease to zero when linked with a single turn induces in the turn a voltage whose time integral is one volt-second. One weber equals 10^8 maxwells.

2.71 Winding Loss (Copper Loss), P_W — The power expended, as heat, in the conductors of an inductor or resistor, or both, due to the electric current in them.

ANNEX A

(*Foreword*)

CONVERSION FROM GAUSSIAN TO SI UNITS

Multiply the Number for		by	To Obtain the Number	
Gaussian Quantity	Unit		SI Quantity	Unit
Magnetic flux, ϕ	Mx	10^{-8}	Magnetic flux, ϕ	Wb
Flux density, B	G	10^{-4}	Flux density, B	T(Wb/m^2; Vs/m^2)
Magnetic field strength,	Oe	$10^3/4\pi$	Magnetic field strength, H	A/m
Magnetization, M	G or Oe	10^3 $4\pi.10^{-4}$	Magnetization, M Magnetic polarization., J	A/m T
Magnetization, $4\pi M$	G or Oe	$10^3/4\pi$ 10^{-4}	Magnetization, M Magnetic polarization, J	A/m T
Magnetization, M	μB/atom or μB/formula unit	1	Magnetization, M	μB/atom or μB/formula unit etc*
Magnetic moment, m	erg/G	10^{-3}	Magnetic moment, m	J/T(Am^2)

*Natural units, independent of unit system. However, the numerical value of the Bohr magneton does depend on unit system.

SYMBOLS and UNITS

G=Gauss; Oe=Oersted; T=Tesla; Wb=Weber; μB=Bohr magneton; A=Ampere; V=Volt; S=second; m=metre; J=Joule, Mx=Maxwell.

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